Grids Theme Overview

GO-ESSP Workshop 2009
Max Planck Institut, Hamburg

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Talk outline. . .

1. Examples of grids in use in ESMs
   - Horizontal coordinates
   - Vertical coordinates
2. Why a grid standard?
   - Model makers
   - Model data users
3. Gridspec tools
   - Grid creation
   - Analysis and Visualization
   - Regridding
4. New Directions

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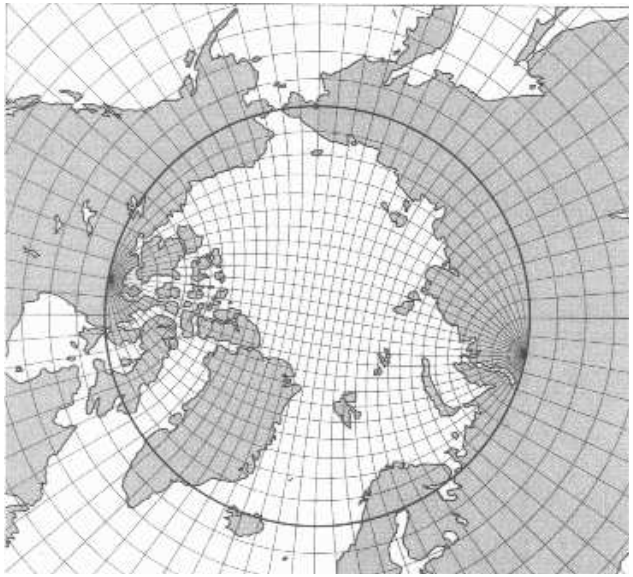
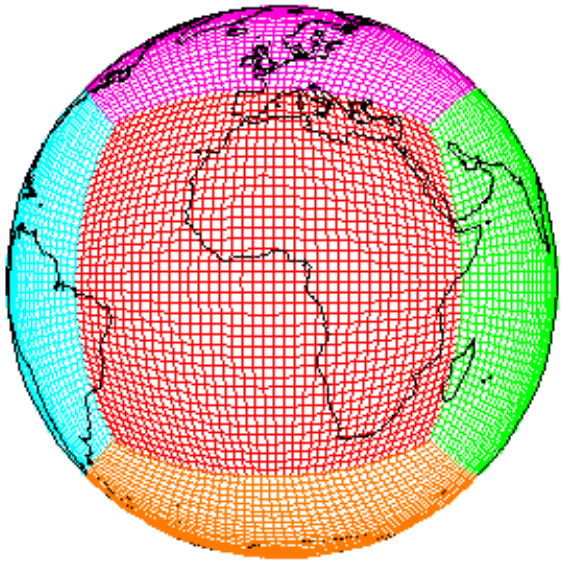
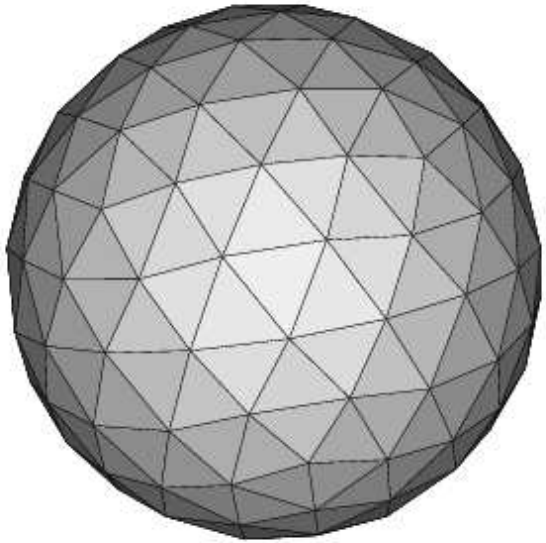
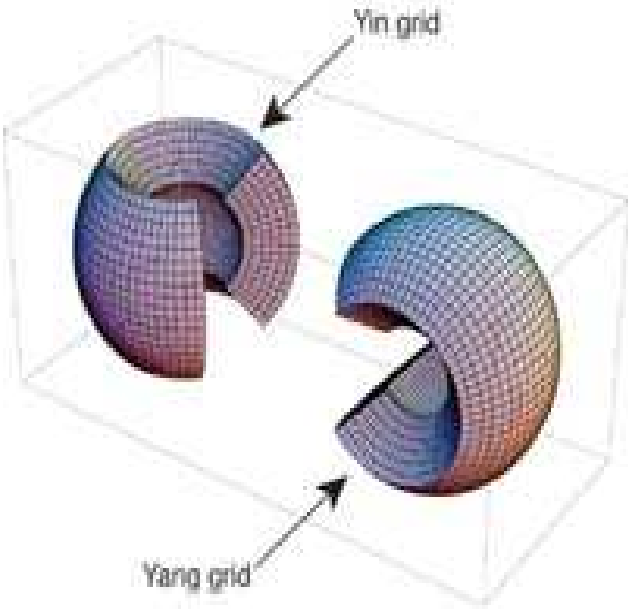
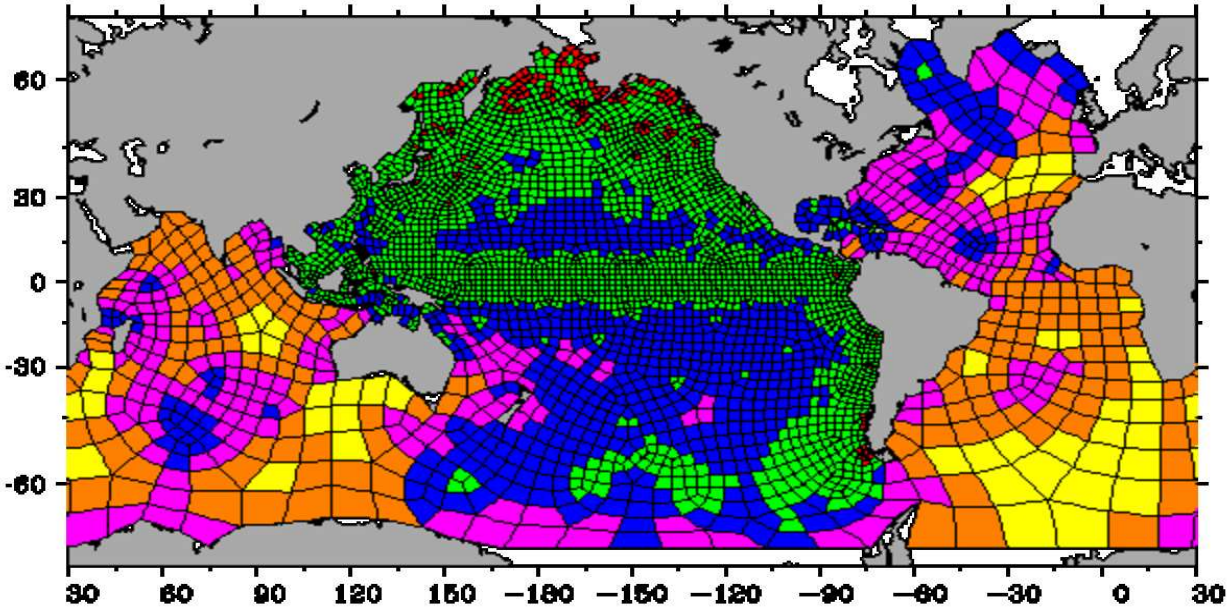
Horizontal grids in use in ESMs



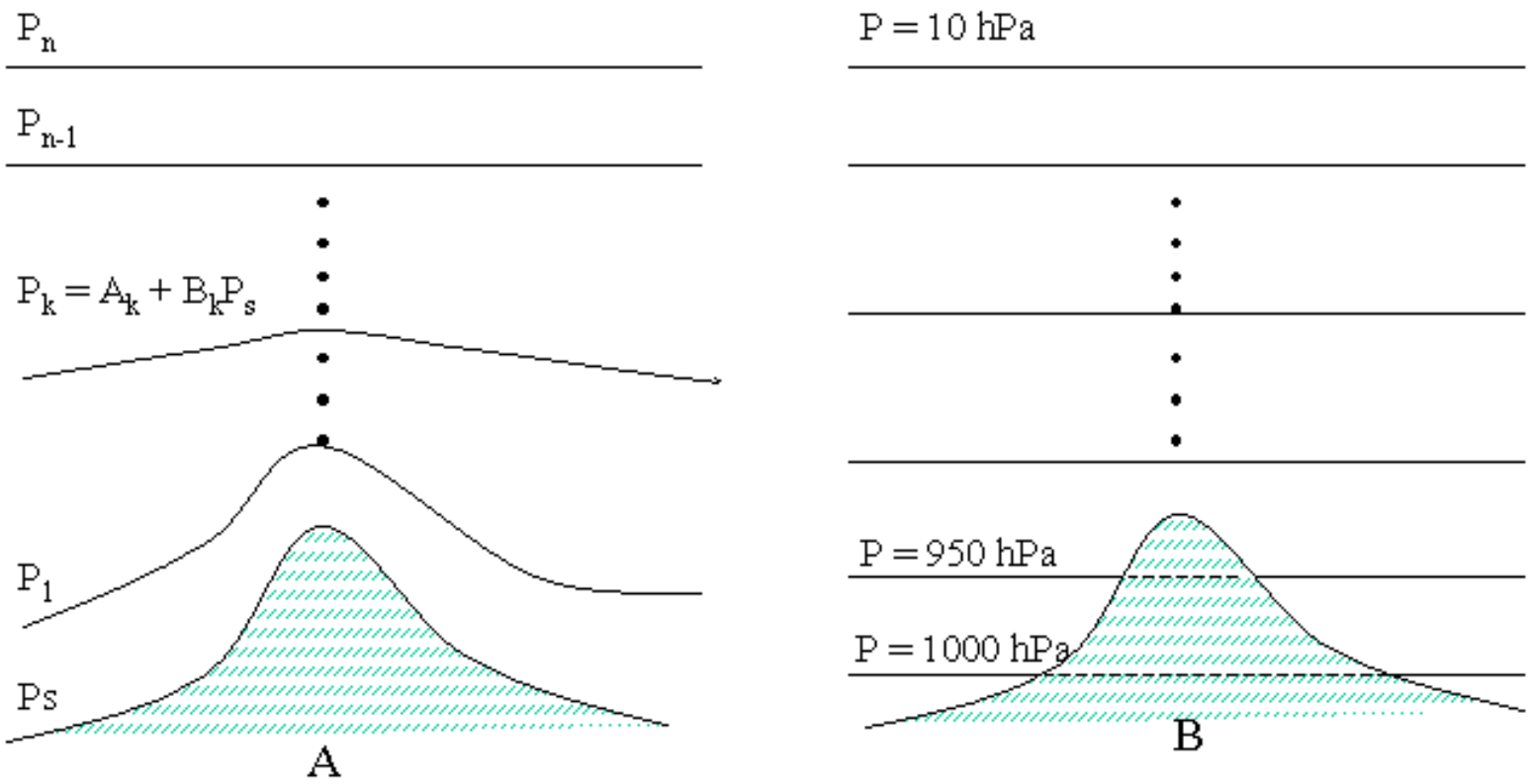








Vertical coordinates



The taxonomy of vertical coordinates distinguishes mass-based and space-based vertical coordinates. There is often an attempt to do something in the spirit of geo-referencing: invoking a “standard” reference grid: usually based on pressure levels in the atmosphere, and depth in the ocean.

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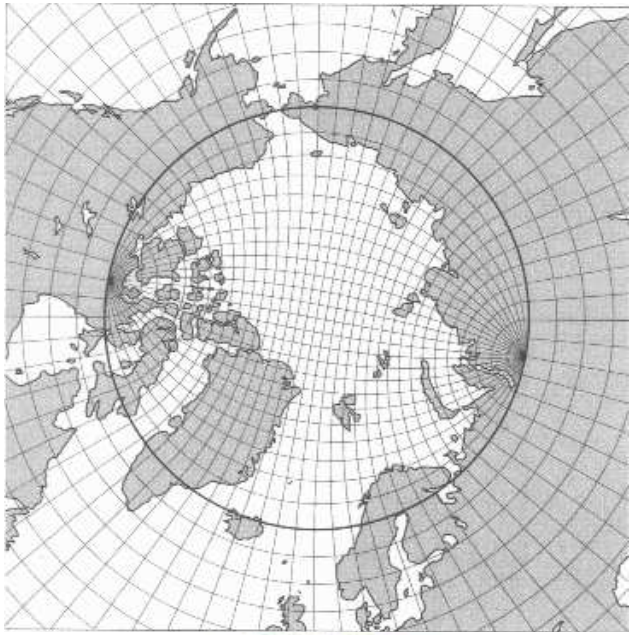
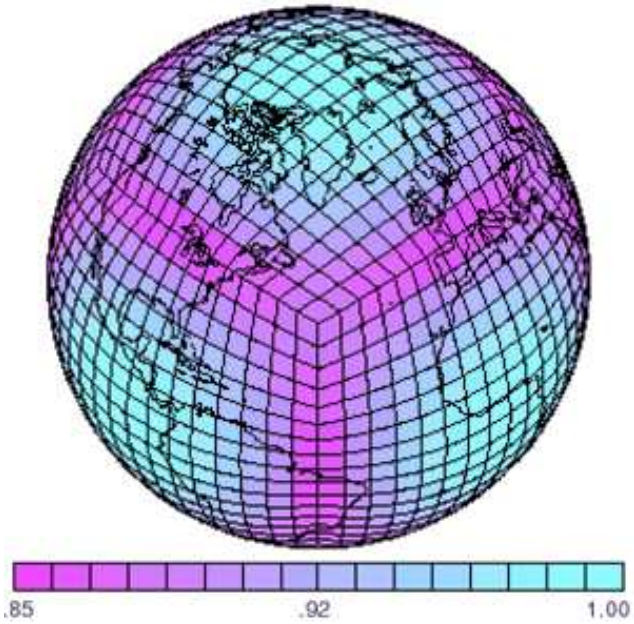
Earth system models are built from components

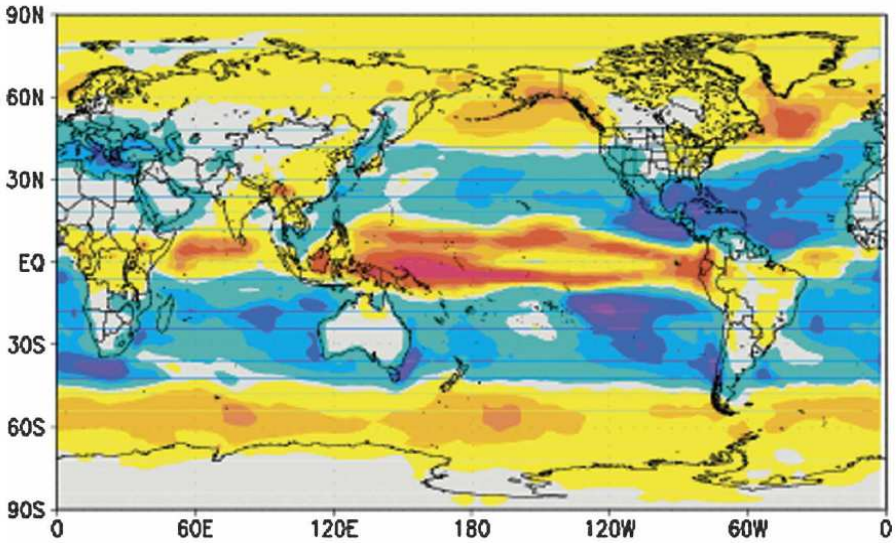
- Earth system models nowadays are built from components: subsystems that may be independently discretized.
- Even when all components are built by a cohesive community, the different components must have some conventions to share grid information.
- Furthermore, these days it is increasingly common to build ESMs out of components of independent provenance.



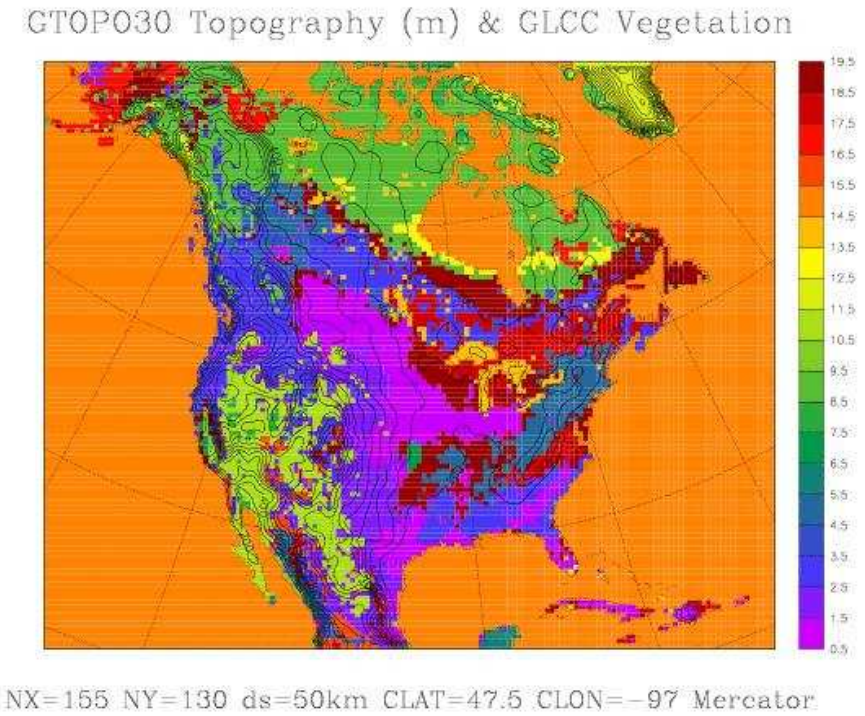


Dependencies across data from many models

- Model intercomparisons have become a primary research avenue for consensus and uncertainty estimates of anthropogenic climate change. This plot is a composite across the entire AR4 archive.



- Model chaining: output from one model used as forcing for another “downstream”.



Grid metadata

To be of use by models as well as for interpreting model output, the standard must enable vector calculus and conservative regridding. The following aspects of a grid must be included in the specification:

- distances between gridpoints, to allow differential operations;
- angles of grid lines with respect to a reference, usually geographic East and North, to enable vector operations. One may also choose to include an arc type (e.g “great circle”), which specifies families of curves to follow while integrating a grid line along a surface.
- areas and volumes for integral operations. This is generally done by defining the boundaries of a grid cell represented by a point value. We will also consider fractional areas and volumes in the presence of a mask, which defines the sharing of cell between two or more components.

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Specifying a grid tile

A command-line tool for creating a horizontal grid file for `horizontal_grid_type = spectral_grid, regular_lonlat_grid, tripolar_grid, conformal_cubic_grid, gnomonic_cubic_grid, simple_cartesian_grid`, e.g

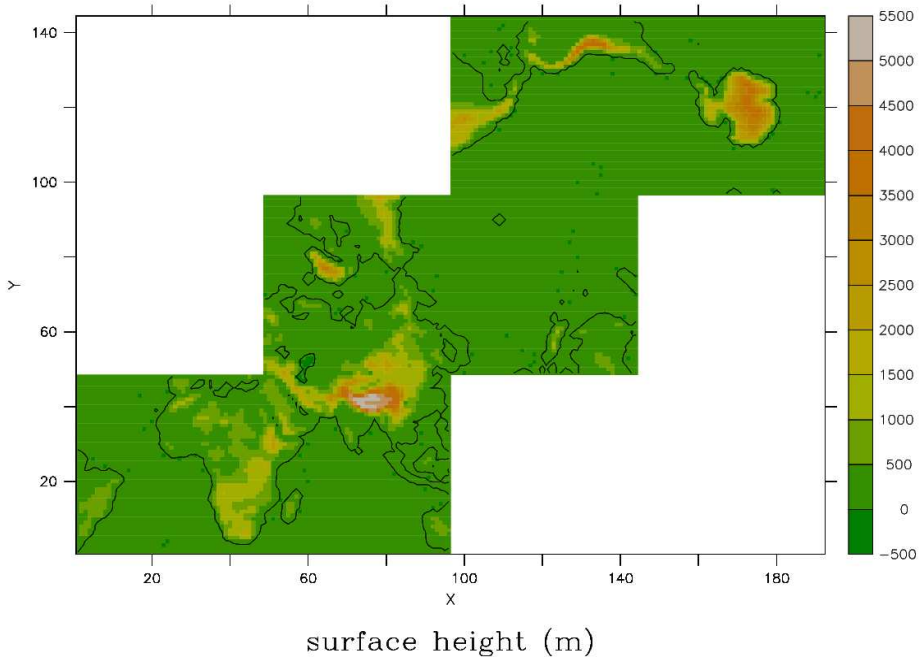
- `make_hgrid -grid_type regular_lonlat_grid -nlon 0,1,3,...360 -nlat -90,-88.2,...` creates a lat-lon grid with non-uniform spacing.
- `make_hgrid -grid_type conformal_cubic_grid -nlon 48 -nratio 2`: created $48 \times 48 \times 6$ cubic grid.

A similar tool called `make_vgrid` for vertical grids.

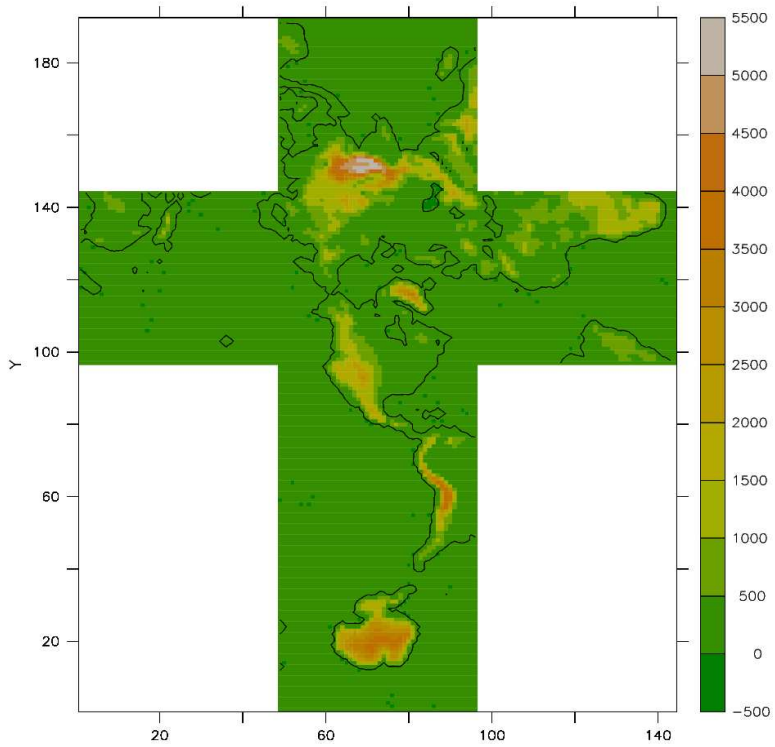
Specifying mosaics

- `make_solo_mosaic -num_tiles ntiles -tile_file gridtile`
  will look for a set of `ntiles` tile gridspec netCDF files named `gridtile#.nc` and make a mosaic file `mosaic.nc` that specifies their linkages.
- `make_topog -mosaic mosaic.nc -topog_type realistic -topog_file /archive/fms/mom4/input_data/OCCAM_p5degree.nc -topog_field TOPO`
  specifies the topography/bathymetry.
- `make_coupler_mosaic -atmos_mosaic atm_mosaic.nc -ocean_mosaic ocean_mosaic.nc -ocean_topog ocean_topog.nc [-land_mosaic land_mosaic.nc] [-sea_level sea_level] [-interp_method 1] [-mosaic_name mosaic_name]` generates a coupler mosaic with land-sea mask, etc.

Analysis and visualization



surface height (m)



`http://www.gfdl.noaa.gov/~atw/ferret/cubed_sphere/`

- Each tile in a mosaic is a self-contained standard netCDF file.
- Reliance on “soft” conventions to relate tiles.
- ferret is building gridspec-based mechanism.

Regridding

`fregrid` is a command-line utility for regridding.

- `fregrid -input_mosaic input_mosaic.nc - nlon M -nlat N -input_file input_file -field_name temp,salt`
- `fregrid -input_mosaic input_mosaic.nc -output_mosaic output_mosaic.nc -input_file input_file -field_name temp,salt`

fregrid is now prototyped as a “web service” (see demo later today!) We could potentially offer server-side regridding, allowing fields to be stored and manipulated on their native grids, but output data on a different grid if desired. (WGOMD recommendation for CMIP5).

Gridspec in CF/netCDF and in CMIP5

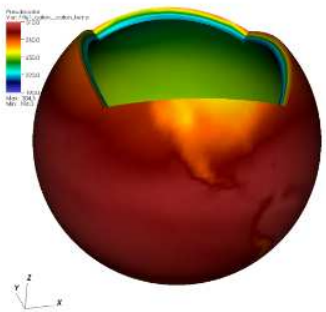
- Based on a collaboration between Ed Hartnett (Unidata) and Zhi Liang and Balaji (GFDL), there is now a Gridspec API.
- Every command-line tool (`make_hgrid`, `fregrid`, etc.) now has an API call.
- Gridspec API to be distributed with the nightly build (i.e bleeding edge) netCDF-4 library. Maintained by GFDL out of the Unidata CVS.
- CMIP5 allows native grid data (CMIP required lat-lon only). Groups supplying native grid data are encouraged to submit gridspec files: tools will be distributed alongside CMOR-2.
- ESG/Curator discovery engine will display select gridspec attributes (thanks to Sylvia Murphy, NCAR and Phil Bentley, UKMO).
- With the ferret web service and the gridspec files, we are working to deploy server-side regridding for CMIP5.

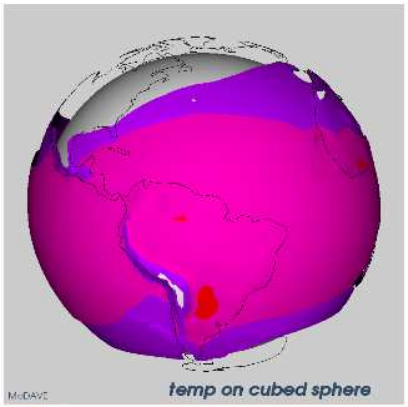
Talk outline . . .

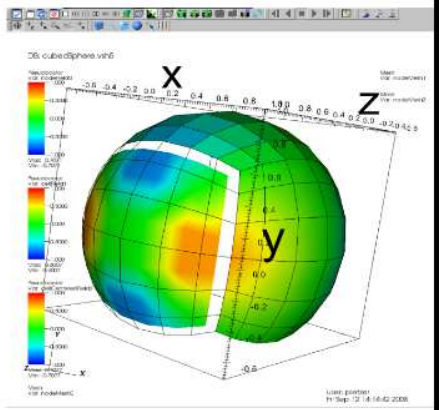
Polytopes

Summary

- Polytopes are hierarchical structures, capable of representing geometries of arbitrary complexity (and in any number of dimensions)
- Arakawa field staggering comes out naturally
- Using polytopes and structured grids (for efficiency) would allow us to cover all possible grids
  - Need to develop interpolation for polys
  - Folding of cubed-sphere grid still a challenge



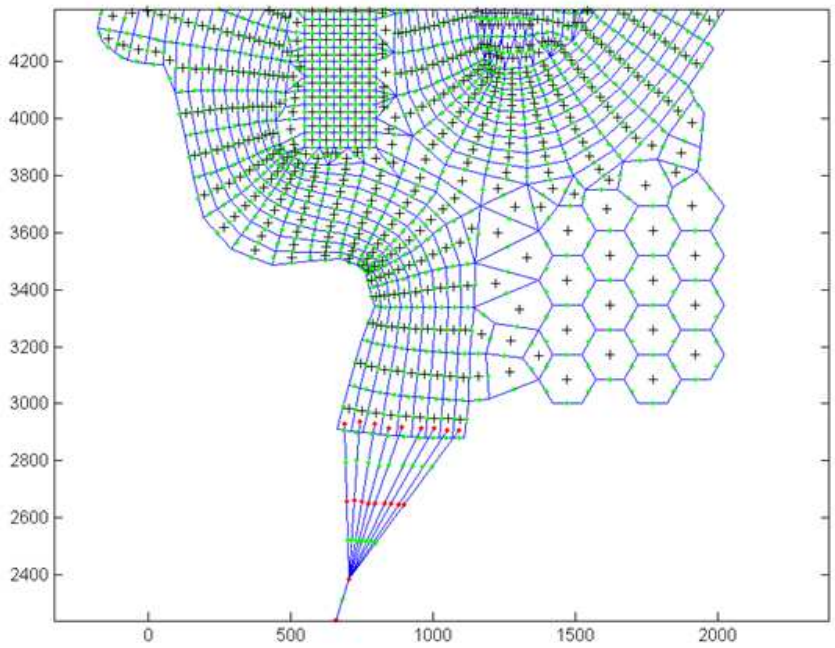




TECH

(Figure courtesy Alex Pletzer, Tech-X and the MoDAVE project.)

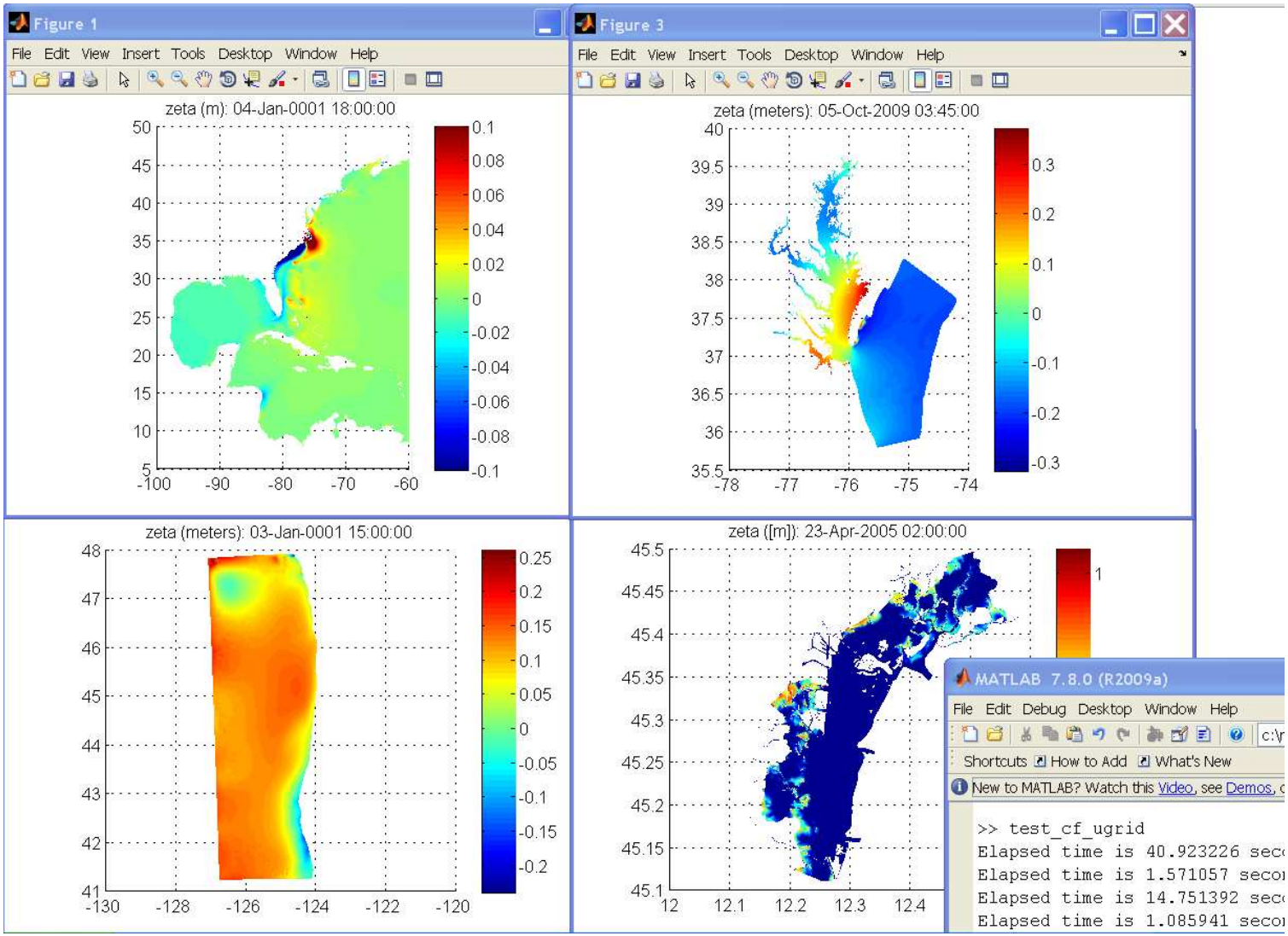
Unstructured grids: netCDF and API




```
netcdf deltares_poly {
dimensions:
  nCell = 700 ;   // The total number of Cells
  nCenter = 613 ; // Number of tris + quads + hexa ('k+' marks)
  nNode = 706 ;   // Number of nodes
  nEdge = 2626 ;  // Number of flux points (green dots)
  nConnect = 6 ;  // Max number of nodes per element
variables:
  int grid1(nConnect, nCell) ; // Mixed edge,center and node data
     grid1:cell_type = "mixed" ;
     grid1:cell_type_array = "cell_types1" ;  //cell_type_array
     grid1:standard_name = "connectivity_array" ;
     grid1:index_start = 0s ;    //  0 or 1
     grid1:coordinates_node = "lon_node lat_node" ;
     grid1:coordinates_center = "lon_center lat_center" ;
     grid1:coordinates_edge = "lon_edge lat_edge" ;
     grid1:edges = "edge1" ;
     grid1:zones = "zone1" ;
  float flux(nEdge) ;
     flux:long_name = "Turbulent Eddy Viscosity For Momentum" ;
     flux:units = "m2 s-1" ;
     flux:grid = "grid1" ;
     flux:grid_location = "edge" ;
     flux:coordinates = "lon_edge lat_edge" ;
  float pressure(nCenter) ;
     pressure:long_name = "Pascals" ;
     pressure:units = "N m-2" ;
     pressure:grid = "grid1" ;
     pressure:grid_location = "center" ;
     pressure:coordinates = "lon_cell"
```

The UGRID consortium (Rich Signell, David Stuebe, Bill Howe, Balaji, Schuchardt, Luettich, others) use an independent netCDF representation based on the `VisTrails` and `GridField` APIs.

Unstructured grids: Matlab screenshot



(Figure courtesy Rich Signell, USGS).